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Analyzing Reliability Indices in Special Protection Schemes in Order to Increase Reliability and Capacity of Transmission Lines

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General Note
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ABSTRACT
Special protection schemes (SPS), known also as remedial action schemes, are those designed to detect one or more predetermined system conditions that have a high probability of causing unusual stress on the power system, and for which preplanned remedial action is considered necessary. The failure of these schemes to accurately detect the defined conditions, or their failure to carry out the required preplanned remedial action, can lead to very serious and costly power system disturbances. It is natural, therefore, that a concern for the reliability of these schemes has been expressed. On this basis, this paper analyzes the reliability of SPS and ensures its outcome with an acceptable probability.

Keywords: Special Protection Scheme, Reliability, Transient Instability, Generator Rejection Scheme

1. INTRODUCTION

System protection schemes (SPS) (also called remedial action schemes, RAS) are designed to detect abnormal system conditions, typically contingency-related, and initiate pre-planned, corrective action to mitigate the consequence of the abnormal condition and provide acceptable system performance (NERC 1997). SPS actions include, among others, changes in load, generation, or system configuration to maintain system stability, acceptable voltages or power flows. SPS is also used as the acronym for special protection scheme, with has the same meaning as system protection scheme. However, it was recommended in (NERC 1997) that word special be replaced by the word system, since it can be argued that all protection is special in some fashion. IEEE uses the System Integrity Protection System (SIPS), RAS is used by (BPA, WECC) others use the term SPS (CIGRE report 2001). Today, in many parts of the world, SPS represents a viable planning alternative to extending transmission system capability. Although SPS deployment usually represents a less costly alternative than building new infrastructure, it carries with it unique operational elements among which are: (1) risks of failure on demand and of inadvertent activation; (2) risk of interacting with other SPS in unintended ways; (3) increased management, maintenance, coordination requirements, and analysis complexity. The objectives of the work described in this report are to summarize the state of the art in regards to SPS including closely related technologies in other industries, provide a structured framework for assessing SPS risk, and examine SPS as a viable planning alternative in which we consider how to identify limits of SPS deployment within a system. These objectives are motivated by the recognition that SPS has proliferated. For example, SCE has 17 RAS on its transmission corridor and has planned to add another 57 (Anderson 1996).

2. SPECIAL PROTECTION SCHEME

Several IEEE papers define a similar term to SPS: System Integrity Protection System (SIPS).Adopting the SIPS definition is not appropriate because it is more inclusive than NERC's definition:" The SIPS encompasses special protection system (SPS), remedial action schemes (RAS),as well as other system integrity schemes, such as under frequency (UF), under voltage(UV), out-of-step (OOS), etc."NERC applies special consideration to UF and UV load shedding schemes in the Reliability Standards and considers OOS relaying in the context of traditional protection systems. Thus, SIPS is not an appropriate term for use in the Reliability Standards, and a new definition of SPSis more appropriate.

3. COMMON APPLICATION OF SPS IN INDUSTRY

Most SPS are used to address a range of system issues including stability, voltage, and loading concerns. Less common applications include arresting sub-synchronous resonance and suppressing torsional oscillations. Actions taken by SPS may include (but are not limited to):system reconfiguration, generation rejection or runback, load rejection or shedding, reactive power or braking resistor insertion, and DC fast ramping.SPS are often deployed because the operational solutions they facilitate are substantially quicker and less expensive to implement than construction of transmission infrastructure. Permanent SPS have been implemented in some cases where the cost associated with system expansion is prohibitive, construction is not possible due to physical constraints, or obtaining permits is not feasible. In other cases temporary SPS have been implemented to maintain system reliability until transmission infrastructure is constructed; or when a reliability risk is temporary (e.g., during equipment outages) and the expense associated with permanent transmission upgrades is not justified. The deployment of SPS adds complexity to power system operation and planning:"Although SPS deployment usually represents a less costly alternative than building new infrastructure, it carries with it unique operational elements among which are: (1) risksof failure on demand and of inadvertent activation; (2) risk of interacting with other SPS in unintended ways; (3) increased management, maintenance, coordination requirements, and analysis complexity."Subsequent sections of this report consider these three operational elements and provide recommendations regarding how they should be addressed in the NERC Reliability Standards.

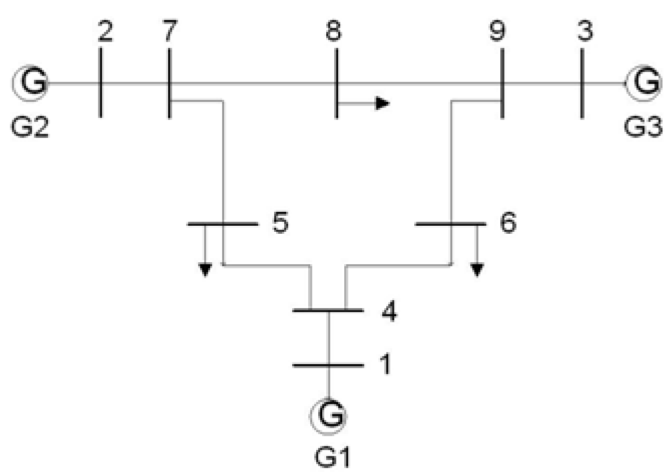

Figure 1 Single line diagram of WSCC 9-bus network

Abbas Farahani and Jalil Ghahramani,
Analyzing Reliability Indices in Special Protection Schemes in Order to Increase Reliability and Capacity of Transmission Lines,
Indian Journal of Engineering, 2016, 13(31), 130-134,

4. CASE STUDY

In this paper, WSCC 9-bus standard network is selected for simulation, Fig. 1. Single line diagram of this network is presented in the following figure and data associated with loads and lines are presented in Table 1 and Table 2.

Table 1 Data of loads of WSCC 9-bus network

Bus number	5	6	8
Load (MW)	200	120	130

Table 2 Data of lines of WSCC 9-bus network in per unit

Line	Susceptances	Reactance	Resistance
4-1	0/0000	0/0576	0/0000
6-4	0/1580	0/0920	0/0170
9-6	0/3580	0/1700	0/0390
9-3	0/0000	0/0586	0/0000
9-8	0/2090	0/1008	0/0119
8-7	0/1490	0/0720	0/0085
7-2	0/0000	0/0625	0/0000
7-5	0/3060	0/1610	0/0320
5-4	0/1760	0/0850	0/0100

This network is simulated in DIgSILENT software. Simulation results show that in case of fault in 7-5, there might be a transient instability in G2 power plant. In this study, this power plant is assumed as combination of 3 identical generators. Results show that if 0.2 sec after the fault on each pre-mentioned lines, one of generators were rejected, there would not be instability in G2. On this basis, a generator rejected scheme can be implemented in G2. The design of this scheme should be in a way that in case of fault in 7-5 line, rejection of these lines be detected and reject one of G2 generators immediately, Fig. 2.

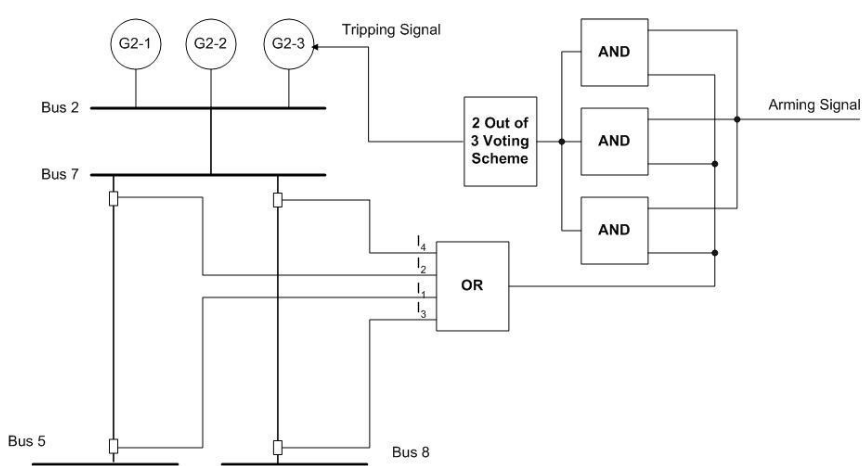

Figure 2 GRS diagram of WSCC 9-bus network in per unit

5. SIMULATION RESULTS

For faults on 7-5 line, a fault in 0-37 percent of bus 7, prediction unit predict instability in G2 and simulations confirm this result. Fig. 3 present this situation.

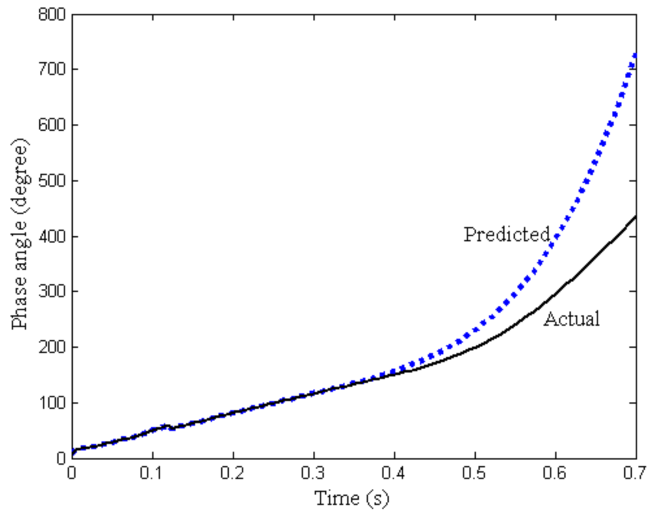

Figure 3 Phase angle of bus 2 for a fault in 15 percent of 7-5 line

For a fault in 38-46 percent of bus 7, prediction unit predict instability in G2, while simulations present stability of G2. Fig. 4 present this situation.

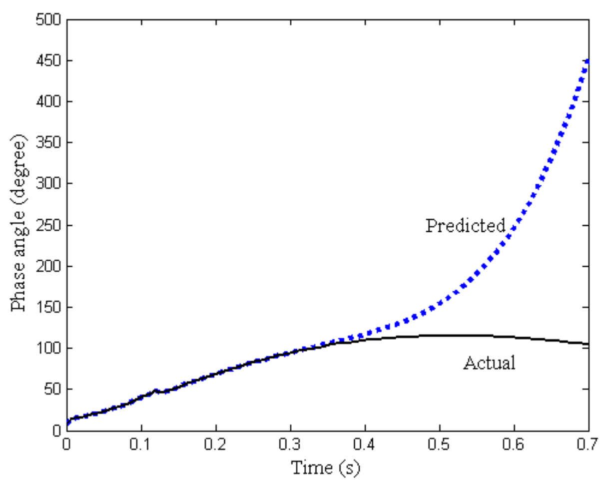

Figure 4 Phase angle of bus 2 for a fault in 40 percent of 7-5 line

For a fault in 47-100 percent of bus 7, both prediction unit and simulations predict stability in G2, Fig. 5 present this situation.

Abbas Farahani and Jalil Ghahramani,
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Indian Journal of Engineering, 2016, 13(31), 130-134,

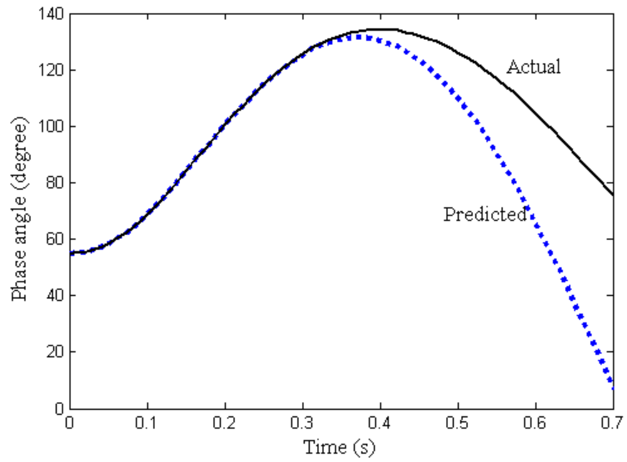

Figure 5 Phase angle of bus 2 for a fault in 80 percent of 7-5 line

6. CONCLUSION

In this paper analyzes the reliability of SPS and ensures its outcome with an acceptable probability. The failure of these schemes to accurately detect the defined conditions, or their failure to carry out the required preplanned remedial action, can lead to very serious and costly power system disturbances. It is natural, therefore, that a concern for the reliability of these schemes has been expressed.

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